EGYPTIAN DENTAL JOURNAL
www.eda-egypt.org

Vol. 68, 3835:3848, October, 2022

Print ISSN 0070-9484 • Online ISSN 2090-2360

Fixed Prosthodontics and Dental Materials

Submit Date : 17-09-2022 • Accept Date : 27-09-2022 • Available online: 01-10-2022 • DOI :10.21608/edj.2022.163452.2266

ACCURACY OF CONVENTIONAL AND DIGITAL IMPRESSIONS AT DIFFERENT SPAN LENGTHS OF MISSING TEETH (COMPARITIVE IN-VITRO STUDY)

Nada A. El-Sheikh*, Rana M. Sherif** *and* Mostafa H. Kamel***

ABSTRACT

Purpose: To assess the accuracy of three impression techniques for different span lengths of missing maxillary teeth.

Materials and methods: Three typodonts were divided into three groups simulating different span length zirconia bridges. **Group S:** 3-unit-posterior bridge, **Group L:** 4-unit-posterior bridge and **Group A:** 6-unit-anterior bridge. Reference standard tessellation language (STL) files were obtained by scanning the typodonts using the desktop scanner inEos X5. Each group was subdivided into three subgroups according to the impression technique used. **Subgroup C:** conventional PVS impression. **Subgroup I:** intraoral scanner (Primescan). **Subgroup E:** extraoral scanner (Medit t300). 15 impressions were taken per group, five per subgroup (n=5). All datasets were obtained in STL format and the conventional impressions were poured with type IV dental stone and digitized using the extraoral reference scanner. Accuracy of the different impression techniques were evaluated via a reverse engineering 3D software for deviation analysis.

Results: A statistically significant difference was found between the 3 different span lengths ($P \leq 0.05$). Primescan showed the lowest trueness values (39.2±1.82μm); (45.7±0.935μm); (77.8±1.73μm) followed by PVS (42.9±0.31μm); (53.8±3.75μm): (74.3±12.4μm) and Medit t300 (78.7±1.21μm); (80.3±1.04μm); (94.9±0.74μm). However, Medit t300 showed the lowest precision values (50.1±10.74μm); (59.64±7.0μm) and (64.39±3.55μm) followed by Primescan (66.8±9.27μm); (73.9±8.45μm) and (92.1±8.30μm) and PVS (78.3±5.38μm); (81.7±8.28μm) and (117.5±8.44μm) for the 3-unit-posterior, 4-unit-posterior and 6-unit-anterior bridges respectively.

Conclusion: Primescan showed the highest trueness, while **Medit t300** showed the highest precision. Increasing the span length reduced the trueness and precision of the tested impression techniques; however, their values were within the acceptable clinical range.

KEYWORDS: Accuracy, span length, polyvinyl siloxane, intraoral scanning, extraoral scanning.

* Post Graduate Researcher, Fixed Prosthodontics Department, Faculty of Oral and Dental Medicine, Misr International University.
** Professor of Fixed Prosthodontics, Faculty of Dentistry, Cairo University.
*** Lecturer of Fixed Prosthodontics Conservative Department Faculty of Oral and Dental Medicine, Misr International University.

INTRODUCTION

One of the most important and fundamental procedures in dentistry is taking an accurate dental impression. It is the negative replica or copy of the intraoral dental soft and hard tissue to produce extraoral physical casts. Impressions have a variety of applications ranging from diagnostic cast production for treatment planning, to patient communication and master cast formation for the fabrication of final restorations[1,2]. The accuracy of the final impression sent to the laboratory technician is significant as it determines the fit of the final restoration[2,3].

Conventional elastomeric impression materials have long been considered as the gold standard due to their high elastic recovery, fine detail reproduction, good dimensional stability and the ability of being poured multiply from single impressions without distortion.[4,5] However, they have some drawbacks as they are time consuming, their models can be easily damaged, they take up physical space and are hard to store.[6] These problems might be reduced by standardizing the workflow but cannot be entirely eliminated.[6]

On the other hand, with the invention of computer-aided design/computer-assisted manufacturing (CAD/CAM), digital scanners have evolved to facilitate the accurate extraction of digital dental models directly from the patient. They act as data collection tools to produce three-dimensional (3D) images of the subject being scanned and tend to eliminate the error caused by impression taking and gypsum model casting.[6]

Digital impressions can be obtained using one of two techniques, either directly by using an intraoral scanner or indirectly by using an extraoral scanner. An intraoral scanner allows the clinician to obtain information from the prepared abutments without the need of a conventional impression, while extraoral laboratory scanners allow the digitization of dental impressions or casts to produce virtual models.[5]

The accuracy of an impression is represented in terms of trueness and precision. Trueness is defined as the deviation from the actual or original state, while precision is described as the degree of reproducibility between multiple impressions.[7]

A digital scanner should be able to identify every impression detail and allow the creation of a virtual model that is as close to the actual model as feasible, with little or no deviation from reality. Trueness can be assessed by overlapping the measurement scans/models on a reference scan/model obtained from a highly accurate industrial or desktop scanner, meanwhile precision can be obtained by overlapping multiple scans from the same scanning technique at different times.[7–11] A reverse-engineering software is then used to create colorimetric maps that show the distances/differences between the scanner and the reference model at the micrometric level.[8]

According to the American Dental Association, the accuracy of a digital impression should not exceed the clinically successful acceptable range of 120 μm.[12–15]

Several studies have demonstrated that digital scanners can produce single unit and short span restorations with equal or even improved accuracy than conventional impressions.[5,6,16,17] Other studies claimed that digital scanners are accurate when scanning half an arch, but when the scanning span increases they fail to produce superior accuracy than conventional impressions.[8,12,18–21] These cases are preferably taken physically and then scanned extraorally to achieve the best results.[22–24]

Therefore, the aim of this study was to assess the accuracy in terms of trueness and precision of three impression techniques (conventional PVS, intraoral and extraoral scanning) for different span lengths of missing maxillary teeth.

Two null hypotheses were suggested for this study, the first one was that there would be no significant differences in the trueness of conventional and digital impression techniques for different span lengths of missing maxillary teeth and the second one was that there would be no significant differences in the precision of conventional and digital impression techniques for different span lengths of missing maxillary teeth.

MATERIALS AND METHODS

Three maxillary typodont models were prepared to simulate different span length zirconia bridges. The typodonts were divided into three groups according to the edentulous span length. **Group S** was modified by removing the right maxillary first molar to simulate a 3-unit short span posterior FPD. **Group L** was modified by removing the left maxillary second premolar and first molar to simulate a 4-unit long span posterior FPD. **Group A** was modified by removing the maxillary anterior two central and two lateral incisors simulating a 6-unit long span anterior FPD.

For standardization purposes, the abutments were reduced using a dental surveyor (AF 30 Nouvag AG, Switzerland) with a straight hand-piece and round-end diamond stone (No. z856 öko DENT, Germany) of known taper 6°.[25] All the abutments were prepared following the principle guidelines of full coverage zirconia FPDs, with 1.5mm axial reduction, 2mm occlusal reduction, 1mm deep chamfer finish line, 0.5mm above the cervical line and 6° convergence angle.[26,27] (Fig.1)

To obtain the reference models, each group was scanned once using the desktop scanner (InEos X5) and the scans were exported and saved into STL files.

Each group (S, L, A) was subdivided into three equal subgroups according to the type of impression technique used. For subgroup C impressions were taken using conventional PVS (Elite HD+, Zhermack, Italy). For subgroup I impressions were taken using an intraoral scanner (CEREC Primescan) and for subgroup E impressions were taken using an extraoral scanner (Medit t300). Each group (S, L, A) received a total of 15 impressions, 5 for every subgroup (n=5). (Table. 1)

The conventional PVS impressions (subgroup C) were taken with a metal stock tray using the two-step-two-viscosity technique. The impressions were poured with type IV extra hard stone (Elite Rock, Zhermack, Italy) after one hour. The dental stone was vacuum mixed and poured under vibration as per the manufacturer's recommendations. [28] After complete setting, the casts were removed and inspected visually for any defects or air bubbles. Any defected casts were discarded. The 15 poured casts were then digitized using the inEos X5 laboratory scanner to convert the physical impressions into 15 STL files for testing.

For the intraoral scanning (subgroup I), the scanning technique was standardized for all scans as

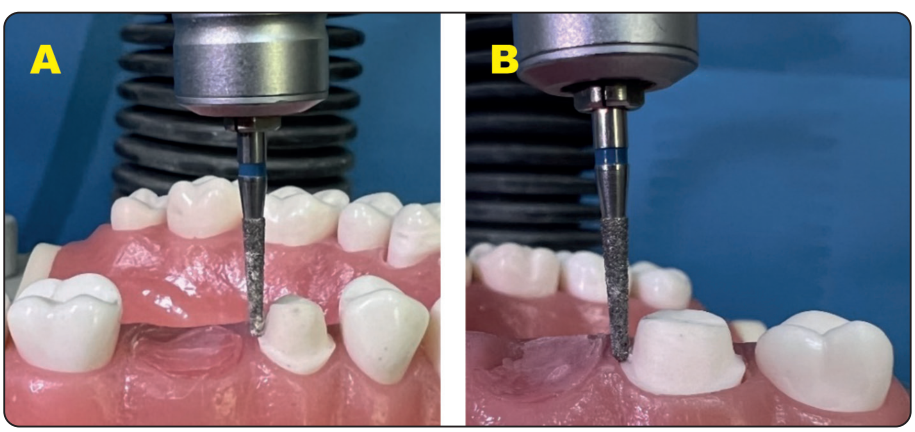

Fig. (1): Preparation of the abutments using a dental surveyor (AF 30 Nouvag AG, Switzerland) with a straight hand-piece and a round-end diamond stone. (No. z856 öko DENT, Germany), where **A:** represents the prepared second premolar and **B:** represents the prepared second molar.

TABLE (1): Sample Grouping

Groups \ Impression Technique	Subgroup C (PVS)	Subgroup I (Intraoral)	Subgroup E (Extraoral)	Total
Group S (3-unit posterior bridge)	SC n= 5	SI n= 5	SE n= 5	n=15
Group L (4-unit posterior bridge)	LC n= 5	LI n= 5	LE n= 5	n=15
Group A (6-unit anterior bridge)	AC n= 5	AI n= 5	AE n= 5	n=15
	n=15	n=15	n=15	**n=45**

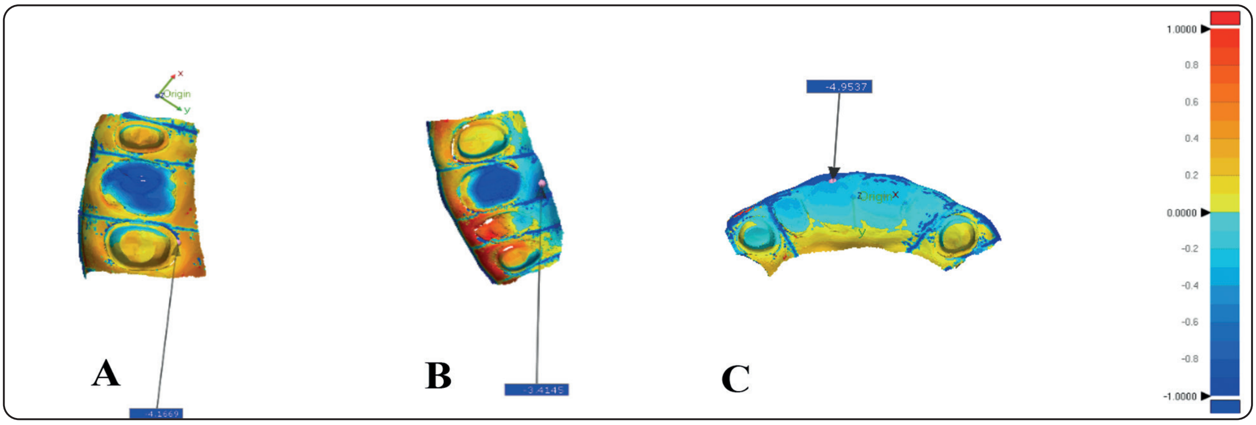

Fig. (2): Color difference map representing the deviation of the 3 spans from their control reference model, where A: represents the short span 3-unit bridge, B: represents the long span 4-unit bridge and C: represents the long span 6-unit bridge.

per the manufacturer's instructions to be continuous, 2-3mm away from the tooth's surface, starting from the occlusal surface of the upper left second molar all the way to the right second molar, then capturing the palatal and interproximal regions followed by the buccal surface of the arch.[29,30] After the scanning was complete, the virtual models were exported and saved as STL files.

To help facilitate the extraoral scanning (subgroup E), the typodonts were placed on a clean dry surface and were sprayed according to the manufacturer's instructions using Cerec optispray (Sirona, Bensheim, Germany) from a distance of 30 cm, to ensure that all the surfaces of the scan model were uniformly covered with powder.[31] Once the models were sprayed they were scanned and saved as STL files.

Accuracy Measurement

For the trueness measurement, a reverse engineering software (Geomagic Control X, North Carolina, USA) was employed to superimpose the reference STL file of each group to each STL file of the five obtained from every subgroup. The reference (InEos X5 files) and measurement (impression technique files) data were imported to the geomagic window and trimmed to remove any data that was not related to the desired scan. First, the initial alignment was selected to ensure that the two model data sets were adjusted in an appropriate position and then the best fit alignment was chosen to certify that they were positioned in one common coordinate system with the least possible mean deviation.[32,33] When two scans were superimposed, the square of the phase difference between a number of points in 3-D space was calculated. The sum of these squares was divided by the number of points, and the Root Mean Square Value (RMS) was calculated, which determines the deviation of the measurement scan from the reference scan. A high calculated RMS value indicates a large error while a low RMS value indicates a small error or deviation.[32]

The software calculates the RMS deviation value using the following equation.

$$RMS = \sqrt{\frac{\sum_{m=1}^{n}(x_{1,m} - x_{2,m})^2}{n}}$$

Where n is the sum of points measured, X_1,m is the measurement of the reference model and X_2,m is the measurement of the tested model.

A color map was drawn with maximum deviation range of 0.5 mm and -0.5 mm minimum deviation with no specific tolerance. The green color region meant perfectly matching surface, the red color region (positive error) indicated that the test model was located above the reference model; model expansion and the blue color region (negative error) meant that the model was located below the reference model; model shrinkage.

All these steps were performed 5 times for every subgroup and 15 times for each group comparing them with their reference scan and a total of 45 reports were generated.

For the precision measurement, the calculation was done inside each group, where each scan in every subgroup was considered as the reference model and the other four scans were superimposed on it to produce a total of 10 reports in every subgroup, 30 reports in every group and 90 reports in total.[34,35] Precision was measured in the same way trueness was calculated from data alignment to reports generation.

Statistical Analysis

Numerical data was explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). For parametric data; one-way ANOVA test was used to compare between different span lengths. Repeated measures ANOVA test was used to compare between conventional and digital techniques. Bonferroni's post-hoc test was used for pair-wise comparisons when ANOVA test is significant. For non-parametric data; Kruskal-Wallis test was used to compare between the span lengths. Friedman's test was used to compare between conventional and digital techniques. Dunn's test was used for pair-wise comparisons when Kruskal-Wallis test is significant. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.

RESULTS

Assessment of trueness (Table 2 and Fig. 3)

For the 3-unit and 4-unit posterior bridges; there was statistically significant difference between the three different impression techniques (*P*-value <0.001, Effect size = 0.870) and (*P*-value <0.001, Effect size = 0.821) respectively. Pair-wise comparisons between them revealed that Subgroup I (Primescan) showed the lowest mean trueness values and thus the best trueness. Subgroup C (PVS) showed lower mean trueness values than Subgroup E (Medit t300) which showed the highest mean trueness values and thus the worst trueness.

For the 6-unit anterior bridge; there was statistically significant difference between the three different impression techniques (*P*-value <0.001, Effect size = 0.630). Pair-wise comparisons between them revealed that Subgroup I (Primescan) showed the lowest mean trueness values and thus the best trueness, followed by Subgroup C (PVS) and Subgroup E (Medit t300). There was no statistically significant difference between Subgroup I (Primescan) and Subgroup C (PVS).

Assessment of precision (Table 3 and Fig. 4)

For the 3-unit posterior and the 6-unit anterior bridges; there was a statistically significant difference between the three different impression techniques (P-value <0.001, Effect size = 0.438) and (P-value <0.001, Effect size = 0.732), respectively. Pair-wise comparisons between them revealed that Subgroup E (Medit t300) showed the lowest mean precision value (least deviation and best precision). Subgroup I (Primescan) showed lower mean precision values than Subgroup C (PVS), which showed the highest mean precision values thus the most deviation and least precision.

While for 4-unit posterior bridges; there was a statistically significant difference between the three different impression techniques (P-value <0.001, Effect size = 0.327). Pair-wise comparisons between them revealed that there was no statistically significant difference between Subgroup I (Primescan) and Subgroup C (PVS); both showed higher mean precision values than Subgroup E (Medit t300), which showed the least deviation and best precision.

TABLE (2): Mean, standard deviation (±SD) values and results of two-way ANOVA test for comparison between trueness values (μm) with different interactions of variables

Bridge types	Subgroup C (PVS)		Subgroup I (Primescan)		Subgroup E (Medit t300)		P-value (Between techniques)	Effect size *(Partial eta squared)*
	Mean	±SD	Mean	±SD	Mean	±SD		
3-unit posterior bridge	42.87^{BF}	0.31	39.22^{CD}	1.82	78.71^{AE}	1.21	<0.001*	0.870
4-unit posterior bridge	53.79^{BE}	3.75	45.68^{CF}	0.93	80.28^{AD}	1.04	<0.001*	0.821
6-unit anterior bridge	74.32^{BD}	12.39	77.82^{BE}	1.73	94.88^{AD}	0.74	0.002*	0.630
P-value (between bridge types)	<0.001*		<0.001*		<0.001*			
Effect size *(partial eta squared)*	0.782		0.857		0.529			

: Significant at P ≤ 0.05,
A, B, C superscripts in the same row indicate statistically significant difference between impression techniques,
D, E, F superscripts in the same column indicate statistically significant difference between bridge types

TABLE (3): Mean, standard deviation (±SD) values and results of two-way ANOVA test for comparison between precision values (μm) with different interactions of variables

Bridge type	Subgroup C (PVS)		Subgroup I (Primescan)		Subgroup E (Medit t300)		P-value (Between techniques)	Effect Size
	Mean	±SD	Mean	±SD	Mean	±SD		
3-unit posterior bridge	78.29^{AD}	5.38	66.75^{BE}	9.27	50.10^{CE}	10.74	<0.001*	0.438
4-unit posterior bridge	81.70^{AE}	8.28	73.94^{AE}	8.45	59.64^{BD}	7.05	<0.001*	0.327
6-unit anterior bridge	117.45^{AD}	8.44	92.04^{BD}	8.30	64.39^{CD}	3.55	<0.001*	0.732
P-value (Between bridge types)	<0.001*		<0.001*		0.001*			
Effect size *(Partial eta squared)*	0.646		0.397		0.170			

: Significant at P ≤ 0.05,
A, B, C superscripts in the same row indicate statistically significant difference between impression techniques,
D, E superscripts in the same column indicate statistically significant difference between bridge types

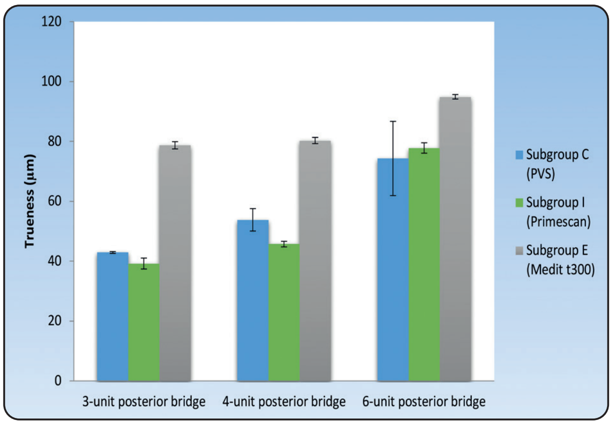

Fig. (3): Bar chart representing mean and ±standard deviation values for trueness (μm) with different interactions of variables.

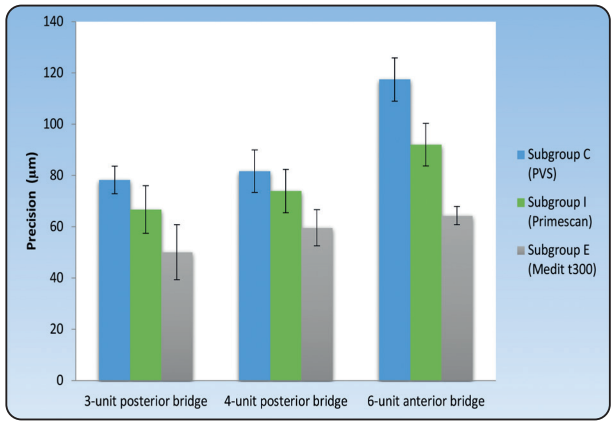

Fig. (4): Bar chart representing mean and ± standard deviation values for precision (μm) with different interactions of variables

DISCUSSION

The purpose of this study was to assess the accuracy in terms of trueness and precision of three impression techniques (conventional PVS, intraoral and extraoral scanning) for different span lengths of missing maxillary teeth.

This study was conducted in vitro to standardize the experimental setting, which is harder to achieve in vivo due to the challenging intraoral environment.[36,37]

Acrylic typodonts (Nissin, Kyoto, Japan) were used to simulate a patient's dental arch and to scan teeth with a refractive index close to that of natural teeth.[25]

The conventional impression selected in this study was a PVS (Elite HD+, Zhermack, Italy) addition silicone as it allows for excellent reproduction of all details due to its hydrophilicity, high elastic recovery, dimensional stability and capacity to be poured multiple times from single impressions without distortion.[38,39]

As previously mentioned, in order to determine the accuracy of an impression, it has to be compared to a reference dataset obtained from a highly accurate scanner. Therefore, in this study, the InEos X5 desktop scanner was selected as the reference because its accuracy was verified according to DIN EN ISO 12836.2015.[40] Literature has also supported the use of inEos X5 as a reference and claimed it to be highly accurate due to its scanning technology (digital stripe light projection with blue light) and the premise that the scanning process is constant thus eliminating the human factor.[41,42]

The intraoral scanner used in this present study was the Cerec Primescan and was chosen because it is one of the latest systems introduced in the market using the new Cerec 5 software that allows processing up to 1,000,000 3D points per second. It is a video and photo based scanner that uses artificial intelligence and has a depth of scanning according to its manufacturer up to 20 mm.[43]

The extraoral scanner selected in this study was the Medit Identica t300 and was chosen for its 7µm accuracy along with its two cameras that use multiple blue LED lines for precise scanning.[31]

For standardization purposes, the abutment preparations were done using a dental surveyor with abrasive stones of known taper according to Mahdy et al.[25] The preparations were done following the principle guidelines for full coverage zirconium restorations according to Praca et al[26] in comparison with those obtained by optical scanners with uncovered finish lines. Methods: Ten human teeth were prepared and forty zirconia crowns were fabricated from STL-datasets obtained from four dental scanners (n = 10 and Asaad et al[27]. A flat occlusal reduction was also done for all abutments as Hmaidouch et al[44], found that copings with flat occlusal surfaces had better internal and marginal fit than anatomic ones.

The conventional PVS impressions were done using a two-step-two-viscosity technique as Kumar et al[39] reported that the one-step impression technique produced less accurate results than the two-step impression technique.

After the stone casts were obtained, they were converted in to STL files using the reference scanner (inEos X5) instead of scanning the impressions as Keul et al[45] stated that scanning the stone models produced more accurate results than directly scanning the impressions.

The scanning strategy was also standardized following the manufacturer's instructions to be continuous with the scanner held horizontally and to start from the occlusal surfaces of posterior teeth as Muller et al[29], Passos et al[30]each using 13 scanning strategies, obtaining 260 digital files (n = 10 per group, Oh et al[46] and Gavounelis et al[47] all stated that this technique yielded the best accuracy because it started at an area with well-defined morphology (occlusal surface of posterior teeth), so the arch's span was registered early in the scanning process and all of the subsequent images were stitched using the best-fit algorithm which represented the best possible image overlap.

When scanning the typodonts using the intraoral scanner (Primescan), powder application was not necessary because according to the manufacturer, Primescan is a powder-less technique.[48] While when using the extraoral scanner (Medit t300), the models were sprayed with Cerec Optispray powder. Powder application was recommended to reduce the reflections of shiny acrylic surfaces and therefore they were sprayed following the manufacturer's instructions from a distance of 30 cm by using a ruler to verify the distance.[31]

There are various methods for assessing the accuracy of dental impressions. The 2D linear measurement of the dental arch geometries and the 3D surface comparison by applying the principle of best fit alignment are examples. The linear 2D approach is preferred when the scannable surfaces have sharp edges or knots such as implant scan bodies, however for freeform surfaces such as teeth and anatomical structures, the 3D surface comparison approach is the one suggested. Therefore, it was chosen for this study, using the reverse engineering software (Control X, Geomagic 2018, USA) as Son et al[32] stated that it is one of the most common and accurate 3D analysis software available.

Multiple 3D difference values could be obtained from a 3D analysis software, the Root Mean Square (RMS) value, the mean and absolute mean deviation values are all examples. In this study the RMS values were calculated because they are claimed to be more accurate than a general arithmetic mean value as they show an estimate of the average error in both positive and negative values.[34,35,49]

Both null hypotheses were rejected, as statistically significant difference was found between the different impression techniques for the different span lengths of missing teeth.

Regarding the different scan spans, the results of this study revealed that the 3-unit posterior bridge had the best trueness and precision, followed in descending order by the 4-unit posterior and the 6-unit anterior bridges.

These results showed that span length is inversely proportional to accuracy and could be attributed to the scanner's stitching mechanism. Digital scanners produce multiple single images that are merged together via stitching. When the scanned area is flat and smooth such as the edentulous span, proper image alignment is difficult and is more prone to errors. Increasing the span length will further complicate the stitching which will result in progressive distortion and hence decreased accuracy.[50–53]

These results were in agreement with many previous studies; Mehl et al[54], stated that single tooth scanning using Cerec Bluecam was more accurate than half arch scanning. Additionally, Su and Sun[37] noticed a decrease in scanning precision for both extraoral and intraoral scanners as the span increased. Similarly, Uhm et al[55], compared the accuracy of inlay scans with 4 unit FPD and found that inlay's accuracy was higher. Moreover, Vacsei et al[56], revealed that for both direct and indirect digitization, the shorter the distance the more accurate the results. Also El Khodary et al[57], stated that long span bridges have an adverse effect on accuracy and that trueness may be affected by the complexity and length of the scanning area. Finally, Celeghin et al[58] and Fattouh et al[13] also stated that as the scanning span increases, the amount of impression distortion increases.

Another reason that could have contributed to the difference in accuracy between the different bridge spans was the abutment type and morphology. Su and Sun[37] and Rudolph et al[59] found posterior abutments to show less deviation than anterior abutments when scanned digitally due to their lower preparation height and inclination. These findings were in agreement with the results of this study, as the lowest accuracy was recorded for the 6-unit anterior bridge.

Regarding the different impression techniques, the best trueness was recorded by Primescan, followed in descending order by PVS and Medit t300. These results could be attributed to Primescan's new scanning technology using the new CEREC 5 software and the ongoing software and hardware advancements in the field of digital dentistry.[13,60,61]

These results were in accordance with Fattouh et al[13] who stated that Primescan had the best trueness when compared with two IOSs (Trios 3, Planmeca Emerald) in relation to three posterior bridges (3, 4 and 5 units) and they attributed their results to the fact that Primescan uses high-frequency contrast analysis and dynamic depth scan that can reach up to 20mm. Additionally, it uses both a video and photo based imaging system. Some studies also showed that imaging system can influence the accuracy of the scanner.[62,63] Jeong et al[63], Yamamoto et al[64] and Kim et al[65] stated that digital impressions obtained by intraoral video scanners showed better accuracy for long span areas than those captured by single image scanners.

Schmidt et al[60], found that the recently introduced Trios 4 and Primescan delivered more accurate results when compared to older IOSs (Trios3Cart and Trios4Pod) for full-arch digital impressions and attributed these findings to the newer and advanced IOS technology. While Haddadi et al[61] and Ender et al[21] found that the software version had significant impact on the accuracy of the IOS, with the recent version (Cerec 5) being more accurate.

In the present study, PVS showed lower trueness compared to Primescan but better trueness compared to Medit t300. The low trueness values could be attributed to PVS being a multi-step procedure. Every step from impression material setting, to impression removal, to stone material pouring and setting to extraoral digitization could contribute to the discrepancy of the impression.[3,66,67]

Another reason that could have contributed to the low trueness values of PVS impressions was the usage of a stock tray instead of a custom tray.[68] Abdou et al[68], stated that the use of custom trays reduced the bulk of the PVS material making them prone to irreversible material distortion.

In this study, Medit t300 showed the lowest trueness values and this could be related to the fact that it was the only group that received powder.

Placing a uniform layer of powder especially with an increased edentulous area, is challenging and is greatly affected by the operator's skill.[67,69,70] Dehurtevent et al[69], stated that experienced dentists achieved greater homogeneity and thinner coatings on crown preparation surfaces than inexperienced ones. Burde et al[71] stated that uneven accumulation of powder on the surface of prepared teeth could have adverse effects on the cement space and marginal fitness of the restoration. Luthard et al[72] reported that powder may lead to errors up to 40 μm. Ender et al[67], stated that during scanning, the powdered surface is frequently disturbed mechanically which might result in scanning artifacts that could be responsible for restoration inaccuracies. Hyun-Su oh et al[73], observed that using a powder type instead of a liquid type scanning aid could lead to the accumulation of powder particles on the model surface forming a thicker coat that could contribute to some level of discrepancy.

Therefore, in this study, the addition of powder that is highly impacted by human error and the constant insertion and removal of the model cast (mechanical disturbance) during scanning could have likely contributed to the low trueness values of the Medit t300 subgroup.

On the other hand, the best precision was recorded by Medit t300, followed by Primescan and then PVS, where statistically significant difference was found between all three impression techniques.

These results could be attributed to the scanning consistency of extraoral scanners as they are automated and not affected by human error.[22,74–76] They were in accordance with Flugge et al[22] who stated that the extraoral scanner (D250) showed higher precision than the intraoral scanner (iTero). These results were also in agreement with Lee et al[74] who found that extraoral scanners were significantly more precise than intraoral ones in cross-arch scans and was attributed to the scanner's scanning consistency, multiple cameras and movable plate that helps improve the scanning angle. However, the results were in disagreement with Schimizu et al[76] who stated that the precision of extraoral scanner (D810) showed no statistically significant difference than IOSs (Omnicam and Trios) for single tooth scanning. These controversial results could be attributed to differences in the scanners and scanning fields investigated.

The lower accuracy values recorded for the 6-unit anterior bridge in all subgroups (PVS, Primescan and Medit t300) could be attributed to the morphology of the canine abutment teeth. Jeon et al[77], stated that canines have a narrow and deep shape that resulted in more shadowing compared to premolar and molar abutments.

Although the results were significantly different between all tested groups, they were all within the clinically acceptable accuracy range of 120µm or less.[12–15,78]

A direct comparison of the findings of this present study with those of other research may be difficult because of variations in the study protocol, differences in the scanning fields and scanners being investigated, the teeth materials being scanned, the scanning software being used and the 3D analysis software. Therefore, it is challenging to draw firm conclusions about the accuracy of various impression techniques based on individual studies. One of the limitations of this study was that it was conducted in-vitro and not in-vivo as clinical conditions including patient's movement, soft tissue movement, limited intraoral space, presence of bleeding and saliva might have had an adverse effect on the scanning accuracy. Also acrylic typodont models do not have the same refractive index as natural teeth. Another limitation was the use of a desktop scanner, not an industrial scanner, as industrial scanners are more powerful. In addition, only one type of each impression technique was used.

CONCLUSION

Within the limitations of this study, the following could be concluded:

1. Increasing the span length reduced the trueness and precision of the three tested impression techniques.
2. Intraoral scanner (Primescan) showed the highest trueness. Extraoral scanner (Medit t300) showed the highest precision.
3. Regardless of the span length, all impression techniques used in this study showed acceptable levels of accuracy (120 μm or less).

REFERENCES

1. Dalstra M, Meisen B. From alginate impressions to digital virtual models: Accuracy and reproducibility. J Orthod. 2009;36(1):36–41.
2. Conrad HJ, Pesun IJ, DeLong R, Hodges JS. Accuracy of two impression techniques with angulated implants. J Prosthet Dent. 2007;97(6):349–56.
3. Ender A, Mehl A. In-vitro evaluation of the accuracy of conventional and digital methods of obtaining full-arch dental impressions. Quintessence Int (Berl). 2015;46(1):9–17.
4. Cho SH, Schaefer O, Thompson GA, Guentsch A. Comparison of accuracy and reproducibility of casts made by digital and conventional methods. J Prosthet Dent. 2015;113(4):310–5.
5. Gjelvold B, Chrcanovic BR, Korduner EK, Collin-Bagewitz I, Kisch J. Intraoral Digital Impression Technique Compared to Conventional Impression Technique. A Randomized Clinical Trial. J Prosthodont. 2016;25(4):282–7.
6. Patzelt SBM, Lamprinos C, Stampf S, Att W. The time efficiency of intraoral scanners. J Am Dent Assoc. 2014;145(6):542–51.
7. Goracci C, Franchi L, Vichi A, Ferrari M. Accuracy, reliability, and efficiency of intraoral scanners for full-arch impressions: A systematic review of the clinical evidence. Eur J Orthod. 2016;38(4):422–8.
8. Imburgia M, Logozzo S, Hauschild U, Veronesi G, Mangano C, Mangano FG. Accuracy of four intraoral scanners in oral implantology: A comparative in vitro study. BMC Oral Health. 2017;17(1):1–13.
9. Ahlholm P, Sipilä K, Vallittu P, Jakonen M, Kotiranta U. Digital Versus Conventional Impressions in Fixed Prosthodontics: A Review. J Prosthodont. 2018;27(1):35–41.
10. Chochlidakis KM, Papaspyridakos P, Geminiani A, Chen CJ, Feng IJ, Ercoli C. Digital versus conventional impressions for fixed prosthodontics: A systematic review and meta-analysis. J Prosthet Dent. 2016;116(2):184-190.e12.
11. Larson TD, Nielsen MA, Brackett WW. The accuracy of dual-arch impressions: A pilot study. J Prosthet Dent. 2002;87(6):625–7.
12. Diker B, Tak Ö. Comparing the accuracy of six intraoral scanners on prepared teeth and effect of scanning sequence. J Adv Prosthodont. 2020 Oct 1 [;12(5):299–306.
13. Fattouh M, Kenawi LMM, Fattouh H. Effect of posterior span length on the trueness and precision of 3 intraoral digital scanners: A comparative 3-dimensional in vitro study. Imaging Sci Dent. 2021;51(4):399.
14. Carbajal Mejía JB, Wakabayashi K, Nakamura T, Yatani H. Influence of abutment tooth geometry on the accuracy of conventional and digital methods of obtaining dental impressions. J Prosthet Dent. 2017 Sep 1;118(3):392–9.
15. Medina-Sotomayor P, Pascual-Moscardo A, Camps A I. Accuracy of 4 digital scanning systems on prepared teeth digitally isolated from a complete dental arch. J Prosthet Dent. 2019 May 1;121(5):811–20.
16. Yuzbasioglu E, Kurt H, Turunc R, Bilir H. Comparison of digital and conventional impression techniques: Evaluation of patients' perception, treatment comfort, effectiveness and clinical outcomes. BMC Oral Health. 2014;14(1):1–7.
17. Joda T, Brägger U. Digital vs. conventional implant prosthetic workflows: a cost/time analysis. Clin Oral Implants Res. 2015;26(12):1430–5.
18. Di Fiore A, Meneghello R, Graiff L, Savio G, Vigolo P, Monaco C, et al. Full arch digital scanning systems performances for implant-supported fixed dental prostheses: a comparative study of 8 intraoral scanners. J Prosthodont ReS. 2019 Oct 1;63(4):396–403.
19. Bilmenoglu C, Cilingir A, Geckili O, Bilhan H, Bilgin T.

In vitro comparison of trueness of 10 intraoral scanners for implant-supported complete-arch fixed dental prostheses. J Prosthet Dent. 2020 Dec 1;124(6):755–60.

20. Latham J, Ludlow M, Mennito A, Kelly A, Evans Z, Renne W. Effect of scan pattern on complete-arch scans with 4 digital scanners. J Prosthet Dent. 2020 Jan 1;123(1):85–95.
21. Ender A, Zimmermann M, Mehl A. Accuracy of complete- and partial-arch impressions of actual intraoral scanning systems in vitro. Int J Comput Dent. 2019;22(1):11–9.
22. Flügge T V., Schlager S, Nelson K, Nahles S, Metzger MC. Precision of intraoral digital dental impressions with iTero and extraoral digitization with the iTero and a model scanner. Am J Orthod Dentofac Orthop. 2013;144(3):471–8.
23. Flügge T, Att W, Metzger M, Nelson K. Precision of Dental Implant Digitization Using Intraoral Scanners. Int J Prosthodont. 2016 May;29(3):277–83.
24. Patzelt SBM, Emmanouilidi A, Stampf S, Strub JR, Att W. Accuracy of full-arch scans using intraoral scanners. Clin Oral Investig. 2014;18(6):1687–94.
25. Mahdy EM, Professor ENA, Professor HI. How to Cite: Effect of abutment tooth geometry on the accuracy of 2 intraoral scanners: In-vitro study. 2809[2]2818 Int J Heal Sci. 2022;6(S4).
26. Praça L, Pekam FC, Rego RO, Radermacher K, Wolfart S, Marotti J. Accuracy of single crowns fabricated from ultrasound digital impressions. Dent Mater. 2018 Nov 1;34(11):e280–8.
27. Sayed Asaad R, Sayed Asaad EDJ Vol R. Marginal Accuracy of CAD/CAM Fabricated Monolithic All-Ceramic Crowns As A function of Digital Scanning Techniques. Egypt Dent J. 2019 Apr 1;65:1925–38.
28. Elite Dental Stones: Dental stones for model preparation.
29. Müller P, Ender A, Joda T, Katsoulis J. Impact of digital intraoral scan strategies on the impression accuracy using the TRIOS Pod scanner. Quintessence Int (Berl). 2016;47(4):343–9.
30. Passos L, Meiga S, Brigagão V, Street A. Impact of different scanning strategies on the accuracy of two current intraoral scanning systems in complete-arch impressions: an in vitro study. Int J Comput Dent. 2019;22(4):307–19.
31. MEDIT T300 User Guide.
32. Son K, Lee WS, Lee KB. Effect of Different Software Programs on the Accuracy of Dental Scanner Using Three-Dimensional Analysis. Int J Environ Res Public Health. 2021 Aug 2;18(16).
33. Ender A, Mehl A. Accuracy in dental medicine, a new way to measure trueness and precision. J Vis Exp. 2014 Apr 29; (86).
34. Oh KC, Lee B, Park YB, Moon HS. Accuracy of Three Digitization Methods for the Dental Arch with Various Tooth Preparation Designs: An In Vitro Study. J Prosthodont. 2019 Feb 1;28(2):195–201.
35. Sim JY, Jang Y, Kim WC, Kim HY, Lee DH, Kim JH. Comparing the accuracy (trueness and precision) of models of fixed dental prostheses fabricated by digital and conventional workflows. J Prosthodont Res. 2019 Jan 1;63(1):25–30.
36. Kurz M, Attin T, Mehl A. Influence of material surface on the scanning error of a powder-free 3D measuring system. Clin Oral Investig. 2015 Nov 1;19(8):2035–43.
37. Su T shu, Sun J. Comparison of repeatability between intraoral digital scanner and extraoral digital scanner: An in-vitro study. J Prosthodont Res. 2015 Oct 1;59(4):236–42.
38. Addition silicone for impression taking.
39. Kumar S. Accuracy of Different Elastomeric Impression Materials Using Dual Arch Impression Trays: An In Vitro Study. 2018;(November).
40. inEos X5: Dental Lab Scanner | Dentsply Sirona.
41. Güth JF, Runkel C, Beuer F, Stimmelmayr M, Edelhoff D, Keul C. Accuracy of five intraoral scanners compared to indirect digitalization. Clin Oral Investig. 2017 Jun 1;21(5):1445–55.
42. Trifković B. Analysis of accuracy and precision of optical 3D digitisation devices in dental computer-aided-design and computer-aided- manufacturing systems.
43. Abad-Coronel C, Valdiviezo P, Naranjo OB. Intraoral Scanning Devices Applied in Fixed Prosthodontics. ACTA Sci Dent Sci. 2019;3:2581–4893.
44. R Hmaidouch,P Neumann WDM. Influence of Preparation Form, Luting Space Setting and Cement Type on the Marginal and Internal Fit of CAD/CAM Crown Copings | Quintessenz Verlags-GmbH.
45. Keul C, Güth JF. Accuracy of full-arch digital impressions: an in vitro and in vivo comparison. Clin Oral Investig.

2020 Feb 1;24(2):735–45.

46. Oh KC, Park JM, Moon HS. Effects of Scanning Strategy and Scanner Type on the Accuracy of Intraoral Scans: A New Approach for Assessing the Accuracy of Scanned Data. J Prosthodont. 2020 Jul 1 ;29(6):518–23.

47. Gavounelis N, Gogola CM, Halazonetis D. The effect of scanning strategy on intraoral scanner's accuracy. 2021.

48. Dentsply sirona CEREC Primescan AC Manuals | ManualsLib.

49. Albdour EA, Shaheen E, Vranckx M, Mangano FG, Politis C, Jacobs R. A novel in vivo method to evaluate trueness of digital impressions. BMC Oral Health. 2018 Jul 3 ;18(1).

50. Kernen F, Schlager S, Seidel Alvarez V, Mehrhof J, Vach K, Kohal R, et al. Accuracy of intraoral scans: An in vivo study of different scanning devices. J Prosthet Dent. 2021

51. Kontis P, Güth JF, Keul C. Accuracy of full-arch digitalization for partially edentulous jaws - a laboratory study on basis of coordinate-based data analysis. Clin Oral Investig. 2022 Apr 1 ;26(4):3651–62.

52. Nedelcu R, Olsson P, Nyström I, Thor A. Finish line distinctness and accuracy in 7 intraoral scanners versus conventional impression: An in vitro descriptive comparison. BMC Oral Health. 2018 Feb 23;18(1):1–11.

53. Resende CCD, Barbosa TAQ, Moura GF, Tavares L do N, Rizzante FAP, George FM, et al. Influence of operator experience, scanner type, and scan size on 3D scans. J Prosthet Dent. 2021 Feb 1;125(2):294–9.

54. Mehl A. (PDF) Accuracy testing of a new intraoral 3D camera.

55. Uhm SH, Kim JH, Jiang HB, Woo CW, Chang M, Kim KN, et al. Evaluation of the accuracy and precision of four intraoral scanners with 70% reduced inlay and four-unit bridge models of international standard. Dent Mater J. 2017.

56. Vecsei B, Joós-Kovács G, Borbély J, Hermann P. Comparison of the accuracy of direct and indirect three-dimensional digitizing processes for CAD/CAM systems – An in vitro study. J Prosthodont Res. 2017 Apr 1; 61(2):177–84.

57. Elkhodary N. Effect of span length on the trueness of an intraoral scanner. (An in-vitro study). Egypt Dent J. 2021 Jul 1 ;67(3):2605–12.

58. Celeghin G, Franceschetti G, Mobilio N, Fasiol A, Catapano S, Corsalini M, et al. Complete-Arch Accuracy of Four Intraoral Scanners: An In Vitro Study. Healthc (Basel, Switzerland). 2021 ;9(3).

59. Rudolph H, Salmen H, Moldan M, Kuhn K, Sichwardt V, Wöstmann B, et al. Accuracy of intraoral and extraoral digital data acquisition for dental restorations. J Appl Oral Sci. 2016 Jan 1 ;24(1):85.

60. Schmidt A, Klussmann L, Wöstmann B, Schlenz MA. Accuracy of Digital and Conventional Full-Arch Impressions in Patients: An Update. J Clin Med. 2020 Mar 1;9(3).

61. Haddadi Y, Bahrami G, Isidor F. Effect of Software Version on the Accuracy of an Intraoral Scanning Device. Int J Prosthodont. 2018 Jul ;31(4):375–6.

62. Park HN, Lim YJ, Yi WJ, Han JS, Lee SP. A comparison of the accuracy of intraoral scanners using an intraoral environment simulator. J Adv Prosthodont. 2018 Feb 1;10(1):58–64.

63. Jeong I Do, Lee JJ, Jeon JH, Kim JH, Kim HY, Kim WC. Accuracy of complete-arch model using an intraoral video scanner: An in vitro study. J Prosthet Dent. 2016 Jun 1;115(6):755–9.

64. Yamamoto M, Kataoka Y, Manabe A. Comparison of digital intraoral scanners by single-image capture system and full-color movie system. Biomed Mater Eng. 2017 ; 28(3):305–14.

65. Kim RJY, Park JM, Shim JS. Accuracy of 9 intraoral scanners for complete-arch image acquisition: A qualitative and quantitative evaluation. J Prosthet Dent. 2018 Dec 1 ;120(6):895-903.e1.

66. Ender A, Attin T, Mehl A. In vivo precision of conventional and digital methods of obtaining complete-arch dental impressions. J Prosthet Dent. 2016;115(3):313–20.

67. Ender A, Zimmermann M, Attin T, Mehl A. In vivo precision of conventional and digital methods for obtaining quadrant dental impressions. Clin Oral Investig. 2016 Sep 1 ;20(7):1495–504.

68. Abduo J. Accuracy of casts produced from conventional and digital workflows: A qualitative and quantitative analyses. J Adv Prosthodont. 2019 Apr 1;11(2):138–46.

69. Dehurtevent M, Robberecht L, Béhin P. Influence of dentist experience with scan spray systems used in direct CAD/CAM impressions. J Prosthet Dent. 2015;113(1):17–21.

70. Zimmermann M, Mehl A, Mörmann WH, Reich S. Intraoral scanning systems - a current overview. Int J Comput Dent. 2015;18(2):101–10129.

71. Burde AV, Dudea D, Cuc S, Moldovan M, Septimiu Campian R. Three-dimensional Evaluations of the Coating Thickness of Two Optical Conditioning Scanning Sprays. 2016;53(1).

72. Luthardt RG. Accuracy of intraoral data acquisition in comparison to the conventional impression; 2005.

73. Oh HS, Lim YJ, Kim B, Kim WH, Kim MJ, Kwon HB. Influence of Applied Liquid-Type Scanning-Aid Material on the Accuracy of the Scanned Image: An In Vitro Experiment. Mater (Basel, Switzerland). 2020 May 1;13(9).

74. Lee SJ, Kim SW, Lee JJ, Cheong CW. Comparison of Intraoral and Extraoral Digital Scanners: Evaluation of Surface Topography and Precision. Dent J. 2020 Jun 1;8(2).

75. Boening KW, Walter MH, Schuette U. Clinical significance of surface activation of silicone impression materials. J Dent. 1998; 26(5–6):447–52.

76. Shimizu S, Shinya A, Kuroda S, Gomi H. The accuracy of the CAD system using intraoral and extraoral scanners for designing of fixed dental prostheses. Dent Mater J. 2017 ; 36(4): 402–7.

77. Jeon JH, Kim DY, Lee JJ, Kim JH, Kim WC. Repeatability and reproducibility of individual abutment impression, assessed with a blue light scanner. J Adv Prosthodont. 2016; 8(3):214.

78. McLean JW, Von F. The estimation of cement film thickness by an in vivo technique. Br Dent J. 1971 Aug 3; 131(3):107–11.